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14. ABSTRACT- The leading cause of death on the battlefield is uncontrolled hemorrhage. Non-compressible (truncal) hemorrhage is the cause over two thirds of these deaths. This makes truncal hemorrhage the leading cause of potentially survivable death on the battlefield. Over one third of the casualties who arrive at the emergency department (ED) or combat surgical hospital (CSH) in need of a blood transfusion are already suffering from acute traumatic coagulopathy which is associated with an 80% mortality. Early aggressive treatment and prevention of this coagulopathy through hemostatic resuscitation has been shown to increase survival. Hemostatic resuscitation involves the very early use of blood and blood products as primary resuscitation fluids to both treat intrinsic acute traumatic coagulopathy and prevent the development of dilutional coagulopathy. Few, if any, of the products used in hemostatic resuscitation are currently available to the Special Operations Forces (SOF) medic. Warm fresh whole blood transfusions could be a powerful tool for the SOF medic to use in order to begin hemostatic resuscitation in the field.					
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The Use of Fresh Whole Blood Transfusions by the SOF Medic for Hemostatic Resuscitation in the Austere Environment

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ABSTRACT

The leading cause of death on the battlefield is uncontrolled hemorrhage.^{1,2} Non-compressible (truncal) hemorrhage is the cause over two thirds of these deaths.³ This makes truncal hemorrhage the leading cause of potentially survivable death on the battlefield.⁴ Over one third of the casualties who arrive at the emergency department (ED) or combat surgical hospital (CSH) in need of a blood transfusion are already suffering from acute traumatic coagulopathy which is associated with an 80% mortality.⁵⁻¹¹ Early aggressive treatment and prevention of this coagulopathy through hemostatic resuscitation has been shown to increase survival.^{5,6,8,12,13} Hemostatic resuscitation involves the very early use of blood and blood products as primary resuscitation fluids to both treat intrinsic acute traumatic coagulopathy and prevent the development of dilutional coagulopathy. Few, if any, of the products used in hemostatic resuscitation are currently available to the Special Operations Forces (SOF) medic. Warm fresh whole blood transfusions could be a powerful tool for the SOF medic to use in order to begin hemostatic resuscitation in the field.

DISCLAIMER: The recommendations in this manuscript are only guidelines and are not a substitute for good clinical judgment. The views and opinions expressed in this manuscript are those of the authors and do not reflect the official policy or position of the Army Medical Department, Department of the Army, the Department of Defense, or the U.S. government.

Part of the current standard of care for hemostatic resuscitation is the use of component therapy (CT).¹³ CT involves targeted use of the various parts of blood, including red blood cells (RBCs), plasma, and platelets, that have been separated from a donated unit. A donated unit of blood is considered “whole blood” before it is separated into its components. The components are combined with anticoagulants and stored frozen or refrigerated prior to use in order to prolong their storage life. CT products need to be thawed and warmed prior to use in order to avoid causing or worsening hypothermia, which in turn inhibits clotting and has been shown to increase mortality.¹⁴⁻²⁶ The storage and administration considerations associated with most CT products make them too logistically burdensome for the SOF medic and therefore largely impractical for the SOF operational environment. At least one SOF unit has a protocol for the use of fresh frozen plasma to be carried freshly thawed by the SOF medic. To date this unit has not used FFP in the field or during TACEVAC due to logistical and tactical considerations.

Massive transfusion (MT) is generally defined as 10 or more units of blood in the first 24 hours after admission.²⁷ The most critically injured patients are the most likely to need a MT of blood.²⁸ The use of CT in MT has been shown to cause a myriad of complications that worsen the lethal triad of coagulopathy, acidosis, and hypothermia.²⁹⁻³⁶ The increased use of blood products is associated with increased mortality, presumably due to the more severely injured casualties needing more blood and blood products.^{37,38} This increase in mortality has been shown to be higher with blood products that have been stored longer.³⁸ The current clinical practice guideline (CPG) from the Joint Theater Trauma Registry (JTTR) and other authors recommend that CT products be used in a ratio identical to whole blood.³⁹⁻⁴² Several studies show improved outcomes using an equal or higher ratio of fresh frozen plasma (FFP): packed red blood cells (PRBC).^{3,9,40,43-55} One retrospective study found a 1:1.4 ratio of FFP to PRBCs to be independently associated with improved patient survival ($p < 0.001$) and also recommended a 1:1 ratio of FFP:PRBCs.⁶ WFWB has more

clotting factors than CT and none of the associated storage problems.

The use of warm fresh whole blood (WFWB) or “buddy transfusions” by the SOF medic is an appealing prospect. In contrast to use in civilian or military medical treatment facilities (MTFs), WFWB may be the only efficacious resuscitation method available



Figure 1: Equipment needed to perform collection of 1 unit of warm fresh whole blood. (Author's collection)



Figure 2: Equipment needed to perform infusion of whole blood. (Author's collection)

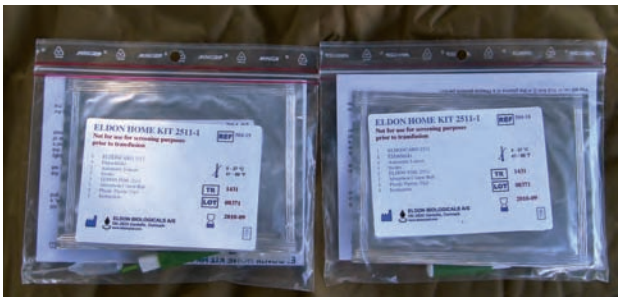


Figure 3: Blood typing cards. (Author's collection)



Figure 4: First line drugs to treat anaphylaxis. (Author's collection)

to combat coagulation disorders associated with hemorrhage.⁵⁶⁻⁵⁸ The amount of equipment needed for WFWB transfusion is relatively small (Figures 1-4), thus making it logistically feasible for the SOF medic. The only additional equipment not normally carried by the SOF medic are a blood collection bag, blood administration set, and blood typing cards. The advantages of WFWB over CT are many (Table 1).^{5,6,59}

While the use of a single unit of WFWB may only be roughly equivalent in volume to a single unit of CT, there are additional factors to consider. As shown in Table 1, WFWB does not need to be warmed, has a higher concentration of RBCs, more platelets, 100% of its original clotting factors, and double the fibrinogen.

	Constituents	Temperature	Hematocrit (% of RBCs)	Platelets	Coag factor %	Amount of fibrinogen	Amount of anticoagulant & additives
WFWB	500ml WFWB	37° C	38-50%	150,000-400,000	100%	1500mg	63ml
Component Therapy	680ml Total 1U PRBC + 1U PLT + 1U FFP + 1 U cry	-30° to 0°C	29%	80,000	65% (of initial)	750mg	205ml

(Adapted from Kauvar, Holcomb, Borgman, et.al.)

All of these aid in the effectiveness of clotting and the transport of oxygen. A unit of WFWB also has fewer anticoagulants, which only worsen the coagulopathic condition you are trying to correct. The use of fresh whole blood (FWB) has been shown clinically to improve the ability of the blood to clot, and even reverse dilutional coagulopathy and provide a hemostatic effect comparable to ten units of platelets.^{60, 61}

The Office of Medical History for the U.S. Army Medical Department (AMEDD) has an extensive history of the U.S. blood program entitled, *The Blood Program in WWII*. It contains over 100 statements, citations from studies, meeting minutes, memorandums, and the like that unequivocally endorse the use of whole blood as part of the comprehensive treatment for patients requiring life saving transfusions.⁶² These observations come from the years just prior to World War I through World War II and up to and including the Korean War. The fact that the use of FWB to treat hemorrhage in trauma patients is a controversial practice can only be attributed to a failure to study history or a significant misunderstanding of that history.⁶³⁻⁶⁵ At the beginning of WWII a system was in place to provide both FFP and the more stable freeze dried plasma (FDP). Whole blood was thought to be highly desirable and efficacious, but logistically impractical. Despite the considerable logistical problems involved, the armed services of the United States decided to implement an unparalleled program of collection, and distribution in all theaters of operation in order to bring whole blood as far forward as possible because it was considered so beneficial. Consider this passage from *The Blood Program in WWII: Supplemented by Experiences in the Korean War*, by Douglas B. Kendrick, Brigadier General, MC, USA (1963).

"The rather general belief at the outbreak of the war that plasma alone could compensate for the loss of whole blood in shock simply reflected the prevailing point of view that blood loss was not necessarily the primary cause of shock. It is not easy, in looking back, to understand how these concepts were ever accepted, yet some of the most competent physicians in the country believed that plasma alone could compensate for the massive blood losses which occurred in trauma. It was a belief which did a disservice to the true and important role of plasma in the therapy of shock. Also, as pointed out elsewhere, many observers who believed that only whole blood was effective in shock did not believe that it would ever be practical to provide it for forward areas.

Attempts to transfer controlled laboratory studies to combat conditions led to confusion, as might have been expected, for they were based upon faulty premises. As Beecher⁶⁶ pointed out, the belief that plasma would be as effective as whole blood in the management of hemorrhagic shock seems to have been derived from laboratory experiments so set up that the number of variables could be strictly limited. There was, of course, no real resemblance between a combat Soldier who had suffered

*a serious wound or wounds and a rabbit lying quietly in its cage after experimental deprivation of 75 percent of its blood volume. The very management of the wounded Soldier, including his successive removal rearward from the battlefield through the chain of evacuation, produced additional trauma, which was further increased by physical and roentgenologic examinations, anesthesia, and operation. Transfer of laboratory conclusions to a combat situation with its additional and widely different variables was simply unsound reasoning, which led to therapeutic confusion."*⁶²

Several authors in various civilian and military circumstances have recommended the use of FWB and WFWB and have shown to be superior in animal studies and of potential clinical benefit.^{13,59,61,65,68-78} During WWII, hundreds of thousands of units of whole blood were transfused in both battlefield and hospital environments and the rate of complications was comparable to those found in stateside civilian hospitals at the time.⁶²

FWB administered at far forward aid stations was credited with increasing the survival rate of wounded troops in Vietnam.⁷⁹ FWB was collected and used successfully in Mogadishu, Somalia, during the Battle of the Black Sea.⁵⁶ Over 6,000 units of FWB were transfused from March 2003 to July 2007 in Iraq and Afghanistan.⁶⁵ One retrospective study that looked at 500 patients receiving massive transfusions found that the 24-hour and 30-day survival were higher ($p=0.018$ and $p=0.002$ respectively) in a group receiving FWB versus a group receiving CT.⁷⁷ The risk of transfusion reactions did not appear to increase with the use of FWB in Iraq and Afghanistan.⁷⁷

The ability of the SOF medic to safely carry out the collection and administration of WFWB in an austere setting has been validated.⁸⁰ SOF personnel have used a training methodology at the Special Operations Combat Medic Skills Sustainment Course (SOCMSSC) since 2004, accounting for well over 105 practice sessions that involved collecting and reinfusing blood back into the same donor. The most common complication was an inability to use the collected blood because the bag was not full enough (approximately 15% incidence). A single case of suspected mild citrate toxicity was reported, presumably from an area of high citrate concentration within the bag that had not been fully mixed with the blood. It is thought that this area of high citrate concentration was infused into the patient when the bag was rolled in order to reinfuse the entire contents of the blood collection bag back into the patient. All of these errors can be eliminated with proper instruction and training in technique. WFWB transfusions were recently used by SOF personnel in North Africa to treat a seriously injured Soldier whose evacuation was delayed for several days.⁵⁷

The challenge is to outfit SOF medics with the proper equipment and training in order to allow them to use this hemostatic resuscitation tool safely and effec-

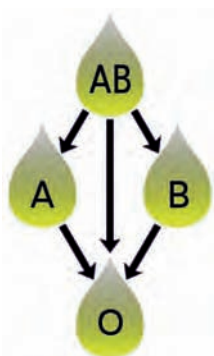


Figure 5: *Plasma Compatibility diagram*
(Wikipedia, GNU licensed)

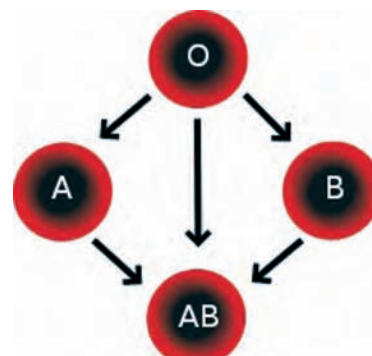


Figure 6: *RBC Compatibility diagram*
(Wikipedia, GNU licensed)

tively. The two major issues that must be addressed are the prevention of transfusion reactions and the transmission of bloodborne pathogens. The prevention of transfusion reactions is already addressed by the use of blood cards that can consistently provide an accurate blood type in less than ten minutes. The recently FDA approved ABORhCard® (Micronics, Inc., Redmond, WA) (Figure 7) can provide a low cost test the size of a credit card to accurately type blood in less than one minute.⁸¹ The risk of transfusion reactions can also be lessened by using the whole blood crossmatch test as described in The Emergency War Surgery Manual.⁸² Two separate efforts are currently underway to allow for rapid crossmatch testing in a small, lightweight test.^{81, 83} While neither the Eldon® nor the Micronics® blood typing cards are intended for prescreening prior to transfusion, current DoD guidelines and a NATO agreement provide for the use of ID cards and ID tags in order to transfuse whole blood during contingency operations.^{84, 85} The use of the blood typing cards is a safeguard to reduce the risk of a hemolytic reaction resulting from incorrect information from ID cards and ID tags (estimated to be incorrect 1.2 to 11% of the time).⁸⁶⁻⁸⁸ Several authors have recommended that stricter controls should be implemented during the production of ID cards and tags. It is also not entirely clear if the errors are attributable to self reporting or clerical errors, so cards and tags should only be produced using a laboratory test for reference. Another important aspect in reducing the risk of a crossmatch reaction is to educate medical providers about the erroneous notion of a “universal donor” for FWB.^{82, 89} The universal donor concept arose from the practice of calling PRBCs blood, when they are technically a blood component. While there is a universal donor for PRBCs, there is no universal donor for FWB.^{58, 90} Only type specific FWB must be given to avoid a hemolytic transfusion reaction (Figures 5 and 6).

In order to lessen the risk of viral transmission associated with FWB, rapid infectious disease screening tests are available that would not significantly in-

crease the overall weight and cube space of the SOF medic’s load. Retrospective testing of FWB unit screened with these tests revealed no false negatives, although the manufacturer only guarantees ranges between 98.2% and 99.4% among the various tests.⁹¹ Donors should all be retrospectively screened IAW the JTTR Clinical Practice Guideline for FWB transfusion which states:

“Retrospective testing for infectious disease markers will be performed on all donor specimens. This testing will be completed at an FDA-approved, DoD-sanctioned laboratory in accordance with FDA/AABB standards of medical care. Four EDTA and one red top tube will be collected for retrospective testing.”

There are currently efforts underway to develop a single, credit card sized test to rapidly rule out the presence of multiple bloodborne pathogens, which should make donor testing quicker and easier.⁸³

Several tactical and logistical factors that should be taken into account prior to deciding whether to perform a fresh whole blood transfusion in an aus-



Figure 7: *ABORh Card®*
(Courtesy Micronics, Inc.)
NSN 6550-01-585-7918 Unit
of Issue: Box of 12 Devices

tere environment. The decision making process that should be undertaken before initiating this procedure is well beyond the scope of this article. The need of the patient, availability of supplies and trained personnel, and the evacuation time must be weighed along with the tactical situation before considering this procedure. It is suffice to say that the decision to perform a fresh whole blood transfusion should be made only after considering all of the possible consequences and weighing them against the benefit of the patient. Chief among these considerations should be the possible catastrophic results to the patient should a hemolytic reaction occur and the degradation to the performance of the donor. At no time should more than one unit of blood be collected from a single donor and the donor should be given 500ml of Hextend or similar fluid following donation.⁶⁵ Optimally the donor should also be in a position to perform light duty for at least 72 hours following donation. Current Army regulations mandate that aircrew personnel are restricted from performing flying duties for this same period of time following whole blood donation.⁹² At no time should evacuation to a higher level of medical care, especially surgical care, be delayed in order to perform a buddy transfusion, but the procedure could conceivably be carried out during TACEVAC in under 30 minutes, depending on the medic's level of proficiency and experience with the procedure.

The clinical considerations involved in the decision to perform a fresh whole blood transfusion are beyond the scope of this article. Presumably the use of WFWB would be considered for uncontrolled truncal hemorrhage. Whether hypotensive resuscitation should be initiated with other fluids prior to considering WFWB transfusion would be an interesting debate, as would the use of other hemostatic resuscitative products. Interestingly, several MT protocols are being evaluated that could conceivably be adapted for use by the SOF medic in order to have a comprehensive resuscitation strategy that incorporates hypotensive and hemostatic resuscitation.⁹⁴⁻¹⁰⁰

The strategy of hemostatic resuscitation has addressed a critical need for patients presenting to EDs and CSHs. However, there are few, if any, tools for the SOF medic to begin any form of hemostatic resuscitation prior to arrival at an MTF. Under the right circumstances, and with the implementation of proper training and safety measures, WFWB transfusions can be that tool.



Whole blood packed in a marmite container on ice for use in the European Theater of Operations. (ETO) WWII. (U.S. AMEDD Office of Medical History)



Shipment of whole blood collected from rear echelon troops in the ETO, December 1944. (U.S. AMEDD Office of Medical History)



Blood in refrigerated marmite cans being unloaded from C-47 on grass landing strip by Soldiers of Blood Depot in France summer 1944. (U.S. AMEDD Office of Medical History)



*Whole blood dropped in a test parachute drop box on Guam. Box was later used by the Navy during the airlift in the Pacific and during the Korean War.
(U.S. AMEDD Office of Medical History)*



Medics administer plasma to wounded Soldier, Utah Beach, June 6th, 1944. (National Archives)



*Whole blood loaded aboard a helicopter for transport. Korea, June 1953.
(U.S. AMEDD Office of Medical History)*



*Navy Corpsman administers plasma to wounded Marine, Marshall Islands.
(Department of Defense, USMC)*



*Whole blood is administered to an airborne casualty, enclosed in metal capsule of a helicopter in Korea. Medical technician holds bottle over the wounded man during the 45-minute flight from the front lines.
(National Archives)*



Casualty receives whole blood at forward aid station on Iwo Jima. (Department of Defense, USMC)



*Soldier receives plasma at forward aid station in Korea.
(National Archives)*



Soldier arrives from 173rd Airborne Brigade frontline aid station with whole blood being pressure infused through an IV line. (Courtesy LTC (Ret.) William C. Gilcrease, 7th MASH, Cu Chi, Vietnam, 1966)



*Wounded Soldier receives whole blood near Ujong, Korea, April 1951.
(U.S. AMEDD Office of Medical History)*



Special Forces medic SSG Bill Scruggs administers IV fluids to wounded team leader CPT Stan Dubiel during battle to retake recently overrun firebase. Ha Than, Vietnam, August 1968. (Associated Press)



*Wounded Soldier receives whole blood aboard pod of MEDEVAC helicopter in Korea, October 1953.
(U.S. AMEDD Office of Medical History)*



Special Forces medic collects warm fresh whole blood during a field training exercise. (Author's collection)



Special Forces medic prepares to reinfuse recently collected warm fresh whole blood collected during a field training exercise. (Author's collection)



Blood at an undisclosed location in Southwest Asia. (Department of Defense, USAF)

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